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TECHNICAL
REPORT

Making Better Use of Bandwidth

Data Compression and Network Management Technologies

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Prepared for the United States Army

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Summary

Operations in Afghanistan and Iraq demonstrated the Army's increasing reliance on communications. Tactical forces on the move and widely dispersed were stressed to communicate voice and data and were unable to exchange database transfers, real-time video, and imagery. These applications take a lot of bandwidth,[1] an especially challenging problem for forces on the move that cannot use high-gain antennas. Furthermore, future demands seem likely to increase. Researchers from RAND Arroyo Center have been seeking ways in which the Army might use bandwidth better, specifically how new compression technologies might help improve information throughput. The objective of compression is to reduce the amount of data required to store or transmit digital information.

Compression Techniques

Compression algorithms can exploit several potential methods of data reduction. One is by improving coding efficiency. Coding inefficiency arises when the standard way of encoding a message unit uses more bits than necessary. For example, using a byte (8 bits) to encode 26 alphabetic characters is inefficient because a byte can encode up to 256 distinct characters. A second way to reduce data is to reduce redundancy in messages. A third way is to approximate the message rather than transmit it exactly. For example, video transmission might suppress minor changes from one frame to the next.[2]

Results

Lossless compression algorithms can achieve compression ratios up to 9:1; lossy compression algorithms can achieve ratios as high as 350:1. However, data compression involves tradeoffs. The most important of these is that the aggressive use of lossy compression yields lower quality. To achieve better quality, lossy algorithms are used more conservatively, yielding compression ratios about an order of magnitude lower than their maximums. More complex

[1] Strictly defined, *bandwidth* is the width of the frequency spectrum of a signal, in Hertz. However, this report uses the term's more common meaning: *data rate*, measured in bits per second (bps). These two definitions are interrelated by Shannon's law of information theory, which states that a communications channel of a certain width has a maximum rate at which information can be transferred. This maximum rate is known as the *channel capacity*.

[2] The technique of using an approximation of the original rather than an exact replica is called "lossy" compression. Those algorithms that do not apply this technique are called "lossless" compression. The highest compression rates are typically achieved with lossy algorithms.

algorithms can be designed to retain quality at high compression ratios, at the cost of increased computation. The needs of users may vary over time, so the use of compression techniques needs to remain flexible. Still, the research indicates that the Army can take advantage of commercial compression technologies, although it needs to define what is an acceptable loss in quality and may also have to provide users with increased computing power.

Network accelerators can improve throughput by factors of 2 to 3. Their use requires changes to network structure and operations, but only for the last link to the user. Network accelerators allow the user to control bandwidth usage so that individuals could specify the amount of compression needed for their specific missions. The combination of new compression techniques with network accelerators lets users manage their individual bandwidth needs and could potentially reduce bandwidth demands by an order of magnitude. While most of these technologies are currently commercially available, their use may require research and development into techniques to enhance real-time streaming data as well as user training to manage needs for quality.

Recommendations

Lessons from Operation Iraqi Freedom imply that the Army will need to make best use of available bandwidth. This report discusses how existing data compression and network management techniques could be applied in the near to medium term to improve performance. These techniques would not "solve the bandwidth bottleneck" but would contribute to better performance with minimal impact on existing networks. These techniques are "low-hanging fruit" that could be harvested to increase performance.

We recommend that the Army do the following:

- Incorporate compression and network acceleration technologies into future systems.
- Identify where Army-specific tailoring could improve on commercial data compression technologies.
- Develop an experimental plan to determine acceptable compression-related losses in quality and to train users.

Of these three recommendations, the last one will prove the most difficult to achieve and in some ways is the most important. The recommendation is that the Army develop a systematic experimentation program to determine user needs on an objective basis and, eventually, to train users on what level of communications support they should expect and request. This recommendation is fundamental to determining the required design of future communications networks for the Army.